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REPORT ON THE ASSIMILATIVE CAPACITY OF THE MATTAGAMI RIVER DOWNSTREAM FROM SMOOTH ROCK FALLS

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Ministry of the Environment

The Honourable
Andrew S. Brandt
Minister

Gérard J. M. Raymond
Deputy Minister

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Prepared by:
Ministry of the Environment
Northeastern Region
Technical Support Section

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TABLE OF CONTENTS

	Page
Executive Summary	6
1.0 Introduction	7
2.0 Field Studies	8
3.0 Survey Results	9
3.1. Chemical Sampling	9
3.2. Dissolved Oxygen & Temperature	9
3.3. Hydrology	10
3.4. Staff gauge measurements	10
3.5. Mean Depths	11
3.6. Sediment Oxygen Demand	11
3.7. Time of Travel	11
3.8. Ultimate BOD	11
3.9. Ancillary Observations	12
4.0 Model Development	13
4.1. Formulation	13
4.2. Calibration	13
4.3. Verification	16
4.4. Sensitivity	18
4.5. Design	19
4.6. Compliance Implications	21
5.0 Conclusion	22
6.0 Recommendations	23
References	24
Tables	25
Figures	29
Appendix - Equipment List	39

Tables

		Page
A.	Field Study Components	8
B.	Sediment Oxygen Demand	15
C.	Model Verification	18
D.	Model Sensitivity	19
E.	Streamflow Requirements	21
F.	Results of Chemical Analysis	25-26
G.	Cross-sectional Measurements	27
H.	Time of Travel Relationships	28

Figures

1. Map of Survey Area

2(A) Dissolved Oxygen Measurements July 6-8, 1982
(B) " " " July 27-29, 1982
(C) " " " Aug. 24-25, 1982

3. Dissolved Oxygen Measurements From Km 18 July and Aug. 1982

4. Mattagami River Streamflow - Summer 1982

5. BOD removal (Kr) and Deoxygenation (Kd)

6. Results of Aug. Calibration

7. Dissolved Oxygen at Highway #11, 1980, 81, 82.

8. Allowable Mill Loading

EXECUTIVE SUMMARY

This report deals with the findings of an investigation into the existing water quality of the Mattagami River downstream of Smooth Rock Falls. Included is the development and application of a mathematical waste assimilation model. This model predicts the response of the dissolved oxygen (D.O.) in the river to the loadings of Biochemical Oxygen Demand (BOD_5) being discharged from the Abitibi-Price mill located in Smooth Rock Falls.

From a chemical, physical and aesthetic point of view the overall condition of the stream as observed in 1982 was relatively healthy. Although no major dissolved oxygen depressions were observed under the temperature and streamflow conditions encountered, such depressions have been recorded previously (summer, 1981).

The load of oxygen demanding waste (BOD_5) presently being discharged from the mill can exceed the assimilative capacity of the river under certain circumstances. Figure 8 summarizes the allowable loading versus streamflow for the river at 18 and 22°C. It is calculated that a maximum BOD_5 loading of 3.1 tonnes per day at a temperature of 22°C and streamflow of 28.3 m^3/s (7Q20) would ensure compliance with the Ministry D.O. objective of 47% saturation at all locations. This is approximately half (½) of the loading measured during the August survey of 1982.

The assimilative capacity of this river is reduced by the dissolved oxygen deficit found immediately upstream from the point of discharge of the mill's effluent. It is possible that a reduction in the log driving/storage activities would result in a significant increase in the upstream D.O. concentration and hence to the allowable loading to the river.

1.0 INTRODUCTION

The Mattagami River is a major watercourse in Northeastern Ontario. It originates in the Gogama area and flows northward for 450 km to its confluence with the Moose River. Streamflows have been measured at the dam at Smooth Rock Falls since 1923 and indicate a mean annual discharge of approximately 115 m^3/s (4060 cfs) (Ref.#1) at this point.

In addition to the Smooth Rock Falls Dam there are several other control structures on the Mattagami River itself and some of its tributaries. These structures provide for a certain amount of regulation of the natural flows, which historically has been primarily to optimize power generation.

In 1980 the Northeastern Region instituted a program of intensive warm weather monitoring of all the major pulp and paper waste receiving streams within the region. As a result of this program a severe dissolved oxygen (D.O.) depression (<3.5 mg/L) was observed on the Mattagami River during August of 1981.

Subsequent to these findings, the District Office responsible for this area requested a study to determine the assimilative capacity of this river.

The objective of the study was to determine the allowable loading of oxygen consuming materials that can be discharged and not reduce the minimum D.O. in the river below the Ministry's objective of 47% of saturation (Ref.#3). This was to be calculated over the expected conditions of streamflow and temperature.

2.0 FIELD STUDIES

To achieve the objective of this investigation a study plan was developed that would evaluate the hydrologic and chemical conditions of the river under as wide a variation of streamflow and temperature as possible. Four surveys were conducted on the river during the summer of 1982 including one when the mill was shutdown (July 6-8). The following (Table A) is a brief summary of these surveys and their components.

Table A - Field Study Components

Date	Conditions		Study Components
	Streamflow m^3/s	Water Temp. °C	
June 23	50.6	16.5	Installed distance markers and staff gauges, measured cross sections to km 18.
July 6-8	43.3	18.5	Measured time of travel, installed recording D.O. meter at km 18, completed installation of km markings, measured cross sections to km 33, collected water samples, gauged river.
July 27-29	63.05	20.5	measured time of travel, collected dredge samples to km 40, collected water samples.
August 24-25	52.95	18	measured time of travel, collected chemical samples and gauged river.

NOTE: During all surveys dissolved oxygen and temperature measurements and staff gauge readings were taken at frequent intervals.

In mid-July, high runoff as a result of a heavy rainstorm, interfered with the collection of data for this study. The streamflow increased from approximately 38 m^3/s to greater than 300 m^3/s in a matter of a few days. These high flows scoured the stream bed and therefor it is assumed reduced the impact of sediment oxygen demanding materials on the oxygen regime. The flow did not recede completely for the rest of the summer (never less than approximately 53 m^3/s).

In addition to the four survey periods, the Water Quality Monitoring program (WQM) was conducted on a weekly basis throughout the summer of 1982. The WQM complimented similar intensive surveys in 1981 and 1982.

3.0 SURVEY RESULTS

3.1. Chemical Sampling

The results of the analysis of samples that were collected during the surveys and from the WQM program have been tabulated and are presented in Table F. The location of all sampling points is presented in Figure 1. The station identification code represents the distance (km) downstream from the Smooth Rock Falls Dam.

Modest increases of most measured parameters are observed downstream of the mill's outfall. The levels of total phosphorus are equal to or slightly above the Ministry's objective of 0.03 mg/L (Ref.#3) upstream of the mill. However, Total 'P' does not decrease significantly in the downstream direction and therefore it is expected that very little of this nutrient is being utilized by the aquatic plant life. The absence of any significant D.O. diurnal fluctuations (see Figure 3) indicates low productivity and respiration of algae and therefore it is assumed that their concentrations are also low.

3.2. Dissolved Oxygen and Temperature Measurements

Dissolved oxygen and temperature measurements were taken on as frequent an interval as logistics would permit. These measurements, which were sufficient to generate the required D.O. profiles, have been plotted with respect to their location in figures 2A, B, and C.. Severe D.O. depressions were not observed during any of the 1982 surveys owing to the relatively low temperature, the high streamflow and the mill loadings encountered during survey periods. In addition to discrete measurements, recording D.O./temp. meters were installed at km 18 for most of the summer and at km 0 during the surveys. The maximum and minimum D.O. from the continuous recorder at km 18 have been plotted in Figure 3. Minor diurnal fluctuations have been observed on the recordings.

3.3. Hydrology

Daily streamflow data measured at the Smooth Rock Falls dam for the summer of 1982 was obtained from Abitibi Price Inc. These data are presented in Figure 4. Of note is the sudden increase in flow during mid-July as a result of a heavy rain storm in the Timmins area. Also it can be seen that the lowest flow period for 1982 was during the July 6th - 8th survey. As a check on the accuracy of these data a few stream gaugings were conducted at approximately km 4 downstream of the dam. The results have also been plotted on Figure 4 and demonstrate the relatively close agreement of the data.

The historic streamflow data (1923-1980) from station 04LB001 was analyzed for its 7 day low flow characteristics (June-Sept). This analysis was originally conducted by the Water Resources Branch, (Ref.#1) using data up to and including 1974. Severely low flows were observed in 1975, 76, and 77 and it was felt that the data should be re-evaluated. The resultant 7 day low flows are:

7Q2	1630 cfs	46.2 m^3/s
7Q5	1320 cfs	37.4 m^3/s
7Q10	1150 cfs	32.6 m^3/s
7Q20	1000 cfs	28.3 m^3/s

Period of record: 1923-1980 (June 1 to Sept. 30)

NOTE: 7Qx: The 7 day low flow that occurs, on the average, once in x years or has a 1/x X 100% chance of occurring in any given year, where x = 2, 5, 10, 20.

3.4. Staff Gauges

Staff gauges were installed at 3 locations on June 23. The 3 sites were selected as being representative of the varying cross sectional configuration of the stream bed. Unfortunately the gauge at km 10 was washed away during the July flood. The staff gauges were read frequently and the measurements have been used to determine the relationship between streamflow and mean depth.

3.5. Mean Depth

Cross section measurements were conducted using a recording depth sounder and an optical range finder at 1 km intervals from km 0 to 22 and at 2 km intervals from km 22 to 40. These results are presented in Table G. A longitudinal trace (centre channel) was also made to check for large variations in the cross-section of the streambed between designated stations.

3.6. Sediment Oxygen Demand

Attempts to collect sediment cores resulted in little or no success primarily due to the rocky nature of the stream bed. Attempts to obtain dredge samples for visual observations resulted in slightly better success, however, there were very few locations that the dredges produced anything but pebbles and small amounts of fresh bark. However this type of sampling device (6" Ponar dredge) does not have the ability to trap any of the fine floculant material that may be present at the sediment/water interface.

3.7. Time of Travel

Time of Travel (ToT) was determined using a dye tracer method. Slugs of Rhodamine WT dye were injected into the mill's effluent outfall and at the head of Fish Rapids (km 22). The location of the dye plume was tracked by fluorescence measurements conducted several times during the following days. The ToT studies were conducted during three of the surveys under distinctly different flow regimes. The measurements permitted the generation of streamflow/ToT equations that span a relatively wide range of streamflow. These relationships have been summarized and are presented in Table H.

3.8. Ultimate BOD (BOD_{∞})

During the July and August surveys special samples were collected at stations km 6, 22 and from the mill effluent. These samples were used

for long term incubations which determine the ultimate BOD (BOD_{∞}). The results from these incubations were used to calculate the K1 ratio (BOD_{∞}: BOD_5) at various locations in the stream. For the August survey the effluent K1 ratio was calculated to be 1.72. A value of 2.23 was determined for the sample taken at km 22, and 2.05 at km 6.

3.9. Ancillary Observations

In addition to the physical and chemical measurements taken during this study, observations of the overall aesthetic appearance were noted. There was very little odour detected that is generally associated with the decomposition of organic materials. Only at two locations (km 1.2 and 36) was there any evidence of major bark and wood fibre deposition. The occasional sighting of fish and the presence of water fowl also were noted.

4.0 MODEL DEVELOPMENT

4.1. Formulation

The model (DOMOD 6) that was used for this analysis is a derivation of the Streeter Phelps DO/BOD model developed several years ago by the MOE Water Resources Branch (Ref. #4). Specific references to this model can be found in the Stream Water Quality Assessment Manual. It has been translated and modified to allow data storage on a HP 9825 microcomputer.

4.2. Calibration

The model was calibrated on the results of a survey conducted on August 24 and 25, 1982. This survey was selected because of the favourable conditions found during the period:

streamflow = 52.95 m^3/s
temperature 18 °C
steady state conditions (very little variation of flow in the preceeding week)
the lowest observed D.O. during 1982.

Due to the inherent variability of the BOD test and production variations it is always difficult to establish an accurate mill loading. For example the 1982 summer monthly reports provided by Abitibi Price revealed a fluctuation in the daily average effluent BOD_5 of from 40 to greater than 250 mg/L. For this analysis the mean of the triplicate sampling (MOE) have been used (96.3 mg/L) along with the mill's reported flow of 0.728 m^3/s to develop an effluent loading. The result is a total mill BOD_5 load of 6.06 tonnes per day which compares well with the average load reported by Abitibi-Price for the month of August (5.4 tonnes/day).

The actual volume of mill effluent is not directly measured at this mill. It is instead estimated from the measurement of inflow to the

mill and some sewer measurements. It is for this reason that attempts to measure the volume of discharge through dye dilution and mass balancing of conservative substances were made. The dilution measurement was found to be impossible due to the outfall configuration and mass balancing attempts gave erratic results. The reported mill discharges were therefore the only source and subsequently were used for this analysis.

BOD_5 values measured at station km 6 appear to be too low in comparison to the downstream stations. This is possibly due to incomplete mixing. Therefore the BOD removal rate coefficient (K_r) and deoxygenation rate (K_d) were calculated by interpolation between the initial dilution of mill BOD_5 with the river (assuming complete mixing) and the BOD_5 as measured at the downstream stations. The K_r and K_d rates are assumed equal (0.56/day), ie. the loss of BOD due to processes such as settling was nil. This is supported by the results of Residual Particulate analysis (Table #1) which indicate only a slight decline in the downstream direction. Figure 5 is a plot of these derived rates.

The determination of Sediment Oxygen Demand (SOD) rates proved to be difficult due to equipment problems and the rocky nature of the stream bed. Sediment cores were not obtained for incubation purposes. Instead the SOD rates used in this model are estimates from rates used in models of other pulp and paper waste receiving streams in the Northeastern Region (Ref.#5, 6, 7). The estimated rates are summarized below (Table B). These rates are volumetric; that is to say they have been adjusted for stream depth. The suspended solids (Residual Particulate) concentrations as indicated in Table 1 are relatively low which would lead to minimal deposition in the quiescent zones of the river and therefore relatively low overall sediment demand. That is consistent with our observations on the scoured nature of the river bed.

Table B Sediment Oxygen Demand Rates

River Reach (km)	SOD @ 18°C mg/L/day
0.7-6	0.2
6-12	0.35
12-18	0.40
18-22	0.40
22-28	0.35
28-34	0.35
34-40	0.50

The development of the reaeration coefficients (K_a) was based on the O'Connor-Dobbins formula (Ref.#8).

$$K_a = \frac{1.34(D_m U)^{0.5}}{H^{1.5}}$$

D_m = molecular diffusion coefficient of O_2 in water (cm^2/hr)

U = stream velocity (cm/s)

H = mean stream depth (m)

The molecular diffusion parameter D_m is temperature dependent calculated from:

$D_m = 8.7 \times 10^{-2} \times e^{(0.159(Tc-20.0))} (cm^2/hr)$

T_c = stream temperature (°C)

Velocities for this equation were derived from the ToT studies and therefore represent mean velocity. Mean depths were obtained from cross sectional measurements. For calibration the K_a's were varied within limits (±50%) from their initial calculated values. Due to large variations in depth between cross sectional measurements it was felt that the mean depth component of the O'Connor-Dobbins equation could be adjusted (within reason) to produce the K_a values used during calibration. The K_a's selected range from a low of 0.2 day^{-1} (km .7 to km 6) to a high of 1.2 day^{-1} (km 18-22). The higher rate downstream of km 18 is significant because it becomes the driving force that starts the recovery of the oxygen regime.

The initial input (background conditions) to any model of this type is very important and necessitates accurate assessment of the upstream conditions. A recording dissolved oxygen meter was installed during this survey at km 0. The meter was checked and recalibrated frequently and the average dissolved oxygen observed/recorded for this period was calculated as 7.8 mg/L (83% saturation at 18°C).

In addition to the upstream D.O. the input of BOD_5 was assessed. The results of a triplicate sampling produced a mean value of 0.43 mg/L. This is a relatively low BOD_5 for this area but compares favourably with the results from the Water Quality Monitoring program.

The results of the August calibration have been plotted and are presented in Figure 6.

4.3. Model Verification

The model, as originally calibrated, was for a particular set of conditions which include upstream temperature, flow, BOD_5 and DO. In order to verify the model it must be run using an independent set of conditions. Many of the coefficients and inputs must be adjusted for these new conditions. The following is a listing of the changes that can be made to this model and the components that will be affected.

Change	Effected Components
Temperature	Oxygen Saturation Rate Coefficients Kr, Kd and Ka SOD rate
Streamflow	Time of travel (velocity) Mean depth Rate Coefficient Ka

Several subroutines have been incorporated into the computer program to permit the above alterations.

All temperature conversions are based on van't Hoff's Law:

$$K_{T2} = K_{T1} \cdot \theta^{T2-T1}$$

T1 = original temp. (18°C)
T2 = new temp.
θ = the temperature coefficient associated with the process

The θ values for the various process rates are as follows:

SOD = 1.047
K_r and K_d = 1.075
K_a = 1.024

The saturation concentration (C.S.) of oxygen is calculated using the following equation.

$$C.S. = 14.48 - (.36t) + (.0043\ t^2)$$

t = temperature

Time of travel is adjusted with respect to streamflow using the relationships presented in Table C.

The model was verified using data from five separate surveys. Table C compares observed and predicted values for the verifications.

Table C Model Verification

Date	Min. D.O. (mg/L) Observed	Predicted	Remarks
Aug. 19/81	3.5	4.0	Most severe D.O. deficit observed to date.
	3.5	3.6	The lower predicted D.O. was produced using the BOD_5 reported by Abitibi.
July 7,8/82	8.1-8.5	8.1	Mill was shut down. This was a good test to determine whether the SOD rates or Ka's were reasonable.
July 27,28,29 1982	6.5-6.9	6.4	The SOD was reduced by 50%. This is an estimate of the effect of the scouring resulting from the summer storm.
Aug. 4/82	5.7	5.5	This predicted D.O. was determined using the reported BOD_5 from Abitibi (40 mg/L).
Aug. 10/82	5.8	6.2	Non-steady state conditions (fluctuating streamflow in the week prior to the survey).

4.4. Model Sensitivity

In order to determine the sensitivity of this model to the various inputs, a set of conditions were selected that would remain unchanged while particular variables were adjusted within their expected ranges. The load from the mill was then adjusted to predict the same minimum dissolved oxygen as the base case. The base case is as follows:

River flow = 40 m^3/s
Temperature = 18°C
Upstream BOD_5 = 0.7 mg/L
Upstream Dissolved Oxygen = 6.1 mg/l (65% Sat.)
Effluent BOD_5 = 92 mg/L
Effluent flow = 0.7 m^3/s
Minimum D.O. = 4.72 mg/L

From the following Table D it can be seen that the upstream % saturation appears to have a greater impact on the output of this model than any other factor.

Table D Model Sensitivity

Variable	Method of Variance	Impact on Mill Load
Upstream D.O.	→5.6 (60% Sat.)	28% decrease
	→6.6 (70% Sat.)	27% increase
	→7.0 (75% Sat.)	53% increase
Upstream BOD_5	→6.3 (10% decrease)	5% increase
	→7.7 (10% increase)	5% decrease
	→1.0 (42% increase)	24% decrease
SOD	overall decrease of 10%	3% increase
	overall increase of 10%	6.5% decrease
Ka	overall decreased by 10%	10% decrease
	overall increased by 10%	11% increase
Kr & Kd	decreased by 10%	12% increase
	increased by 10%	10% decrease

4.5. Model Design Case For Assimilation Capacity Prediction

Once the model is determined to be valid it is used as a predictive tool to estimate the allowable mill loading to the river. This allowable loading is that which will not violate the Provincial Water Quality Objective of a minimum of 47% (D.O.) saturation under specified flow and temperature conditions (Ref.#3).

Prior to running this model certain conditions must be evaluated and selected to produce results that will be realistic. These conditions are the streamflow, temperature, upstream D.O. concentration and the upstream BOD_5 concentration.

The range of flows that existed during the field investigations was 43.3 to 63.05 m^3/s. The hydraulic relationships developed at these discharges could be extrapolated, with a high degree of confidence down

to 7Q20 (28.3 m^3/s). As the selected stream flows get further from the observed conditions the accuracy of these relationships will of course decrease.

Two temperatures (18 and 22°C) were selected for this design case. It was felt that these temperatures would span the expected stream temperatures during the low flow season (July, August and September). It is possible however, for slightly higher temperatures to be encountered, as is the case on other major rivers within the area.

The upstream D.O. boundary has been set at 65% of saturation. At this time there are insufficient data available to evaluate the reaeration properties of the Abitibi-Price dam. It is for this reason that the more complete record from the Water Quality Monitoring station at Highway 11 (19-0064-001-02) has been used for this analysis. Figure 7 summarizes the percent saturation as measured by the Water Quality Monitoring Program at Hwy #11 over the past three summers. It can be seen that a significant DO depression (to approximately 65% saturation) has occurred on several occasions. It is for this reason that an upstream boundary D.O. for loading estimation has been set at 65% saturation.

Background or upstream BOD_5 values were reviewed and a value of 0.7 mg/l was selected for this design case.

The results of the model predictions have been plotted in Figure 8. The low point in the sag curve has, from past data, (1982 studies) been observed at kilometer 18 below the Smooth Rock Falls dam. It should be noted that the output from the model predicts that the low point will move upstream when the streamflow decreases to less than approximately 27 m^3/s (950 cfs).

4.6. Compliance Implications

The expected occurrence interval of a violation of the provincial objective of 47% saturation (Sat.) can be roughly estimated from Figure 8. Using the measured mill loading for the August survey (6.06 tonnes/day), the required streamflow for the various conditions that would maintain the D.O. above 47% are presented here:

TABLE E Streamflow Requirement

Conditions Temp(°C)	Background D.O. % Sat.	Required Flow (m^3/s)
18	65	36.0
22	65	49.0
22	70	41.0

By referring to the hydrology section of this report it can be seen that streamflows, on a 2 year return period (7Q2=46.2 m^3/s), are not sufficient to prevent a criterion violation at 22°C and an upstream D.O. saturation of 65%.

The joint recurrence of high temperature, low background D.O. and low streamflow has not been evaluated. The temperature used (22°C) for this example however, is not uncommon for streams of this size in Northeastern Ontario. The most elusive component of this evaluation is obviously the background D.O. concentration. A more accurate prediction of the recurrence will be available when upstream conditions are better defined as additional data are obtained.

5.0 CONCLUSIONS

It is concluded that:

1. The results of this model predict that the potential for severe depressions of the natural oxygen regime are quite high.

2. The most significant factors controlling the levels of oxygen downstream from the Smooth Rock Falls dam are the wastes being discharged from the mill and the relatively high D.O. deficit observed upstream of the dam.

3. There is insufficient effluent flow measurement equipment in place to accurately assess the existing or future mill loads discharged from this mill.

6.0 RECOMMENDATIONS

It is recommended that:

1. An investigation into the cause and possible solutions to the reduced dissolved oxygen levels in the Mattagami River upstream of the dam at Smooth Rock Falls be initiated. This study should also determine the reaeration properties of the dam itself.

2. A flow-measuring/recording device be installed in the final effluent stream at the mill. This device would greatly assist in evaluating the true load of contaminants being discharged from the mill.

3. Data continue to be collected, at all existing stations, through the Water Quality Monitoring Program. This data would provide additional verification and improve the predictive capability of this model.

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Table F

Township: Kendry/Webster/Hurdman

Date	Stn.#	Total P	TKN	Nitrates	Cond.	Turb.	pH	Sulphate	COD	BOD5	Residue Part.	Chlorides
07/07/82	KM 0A	.018	.40	.030	109.0	4.20	7.75	6.7	32	.79	2.840	1.40
07/07/82	KM 0B	.020	.02	.030	109.0	4.30	7.67	6.7	32	.73	2.740	1.40
07/07/82	KM 0C	.018	.43	.025	109.0	4.20	7.54	6.6	32	.78	3.530	1.40
07/07/82	KM 6A	.010	.04	.035	112.0	7.20	7.39	7.0	28	.83	5.130	1.50
07/07/82	KM 6B	.020	.48	.015	112.0	7.10	7.75	7.0	30	.72	4.940	1.50
07/07/82	KM 6C	.038	.45	.035	112.0	6.80	7.70	7.0	32	1.02	3.910	1.45
07/07/82	KM 18A	.025	.48	.030	112.0	4.20	7.57	6.8	32	1.09	4.920	1.40
07/07/82	KM 18B	.015	.45	.035	113.0	6.80	7.98	6.8	30	.93	4.190	1.50
07/07/82	KM 18C	.015	.45	.035	113.0	7.80	7.38	6.8	26	.64	5.480	1.45
07/07/82	KM 22A	.021	.46	.035	111.0	6.70	7.68	6.8	38	.64	5.380	1.45
07/07/82	KM 22B	.013	.45	.025	112.0	6.70	7.65	6.8	38	.81	4.870	1.45
07/07/82	KM 22C	.007	.04	.030	112.0	6.80	7.71	6.8	36	.60	5.100	1.40
27/07/82	KM 0A	.035	.70	.080	94.9	5.90	7.17	6.6	64	1.14	3.800	1.00
27/07/82	EFF A	.530	2.10	.090	1360.0		3.81	159.0	568	94.0		355.00
27/07/82	KM 6A	.033	.75	.070	107.0	7.50	6.80	8.6	62	1.32	6.090	4.30
27/07/82	KM 12A	.035	.73	.075	106.0	7.10	7.00	8.5	60	.87	4.820	3.65
27/07/82	KM 18A	.035	.75	.070	108.0	5.80	7.09	7.4	62	.71	5.400	3.70
27/07/82	KM 22A	.035	.70	.070	108.0	5.70	7.12	7.4	62	.73	4.250	3.60
27/07/82	KM 28A	.028	.72	.070	107.0	5.90	7.44	8.6	66	.74	4.500	3.55
27/07/82	KM 34A	.027	.67	.070	107.0	5.30	7.21	8.0	66	.68	3.920	3.65
27/07/82	KM 40A	.032	.70	.065	108.0	7.10	7.53	8.0	62	.90	3.590	3.50
28/07/82	KM 0B	.033	.73	.085	93.2	7.10	7.44	6.0	68	1.70	4.410	.95
28/07/82	KM 0C	.030	.83	.085	94.5	5.80	7.12	6.1	58	1.38	5.210	1.05
28/07/82	EFF B	.300	1.30	.180	1750.0	33.00	3.00	159.0	568		30.700	348.00
28/07/82	EFF C	.300	1.50	.170	1760.0	31.00	3.00	180.0	588	108.0	32.000	338.00
28/07/82	KM 6B	.040	.75	.060	107.0	6.10	7.10	7.8	60		5.480	4.95
28/07/82	KM 6C	.038	.75	.060	106.0	7.20	7.14	7.8	66	1.44	6.010	4.85
28/07/82	KM 12B	.030	.85	.070	107.0	7.40	7.19	8.0	64	1.48	6.200	4.50
28/07/82	KM 12C	.043	.83	.070	107.0	8.10	7.19	8.0	62	2.02	8.100	4.55
28/07/82	KM 18B	.025	.73	.105	109.0	6.40	7.70	8.1	62	1.07	5.580	4.75
28/07/82	KM 18C	.043	.78	.060	110.0	7.10	7.21	8.2	60	1.21	6.220	4.85
28/07/82	KM 22B	.038	.73	.070	108.0	5.70	7.33	8.1	64		3.960	4.10
28/07/82	KM 28B	.015	.70	.065	107.0	6.80	7.08	8.1	62	.92	3.020	3.75
28/07/82	KM 28C	.033	.73	.065	108.0	6.30	7.07	8.0	58	.86	4.300	3.70
28/07/82	KM 34B	.030	.73	.065	107.0	5.90	7.09	8.0	58	.93	3.900	3.55
28/07/82	KM 34C	.025	.70	.065	107.0	6.20	7.04	7.9	60	.78	4.870	3.55
28/07/82	KM 40B	.030	.73	.060	107.0	5.60	7.48	8.0	56	.76	3.020	3.50
28/07/82	KM 40C	.027	.70	.060	108.0	5.50	7.18	8.5	56	.83	3.020	3.50

Table F (Continued)

Date	Stn.#	Total P	TKN	Nitrates	Cond.	Turb.	pH	Sulphate	COD	BOD5	Residue Part.	Chlorides
25/08/82	KM 0A	.038	.58	.120	110.0	6.30	7.34	6.4	42	.46	3.750	1.15
25/08/82	KM 0B	.030	.54	.105	112.0	5.60	7.50	6.5	36	<.42	3.460	1.20
25/08/82	KM 0C	.031	.57	.110	113.0	5.30	7.45	6.3	40	<.42	4.210	1.20
25/08/82	EFF A	.382	1.25	.125	2280.0	33.00	2.54	174.0	744	97.00	39.000	330.00
25/08/82	EFF B	.360	1.23	.120	2310.0	33.00	2.54	178.0	782	96.50	30.300	285.00
25/08/82	EFF C	.265	1.15	.130	2330.0	34.00	2.55	182.0	742	95.50	35.200	345.00
25/08/82	KM 6A	.038	.61	.060	129.0	6.30	7.26	7.8	44	.88	6.000	4.20
25/08/82	KM 6B	.280	.60	.060	122.0	5.50	7.57	7.7	44	.92	5.350	4.10
25/08/82	KM 6C	.032	.58	.050	121.0	5.10	7.35	7.7	44	.68	5.460	4.15
25/08/82	KM 12A	.031	.59	.045	124.0	5.40	7.17	8.7	52	1.06	5.300	4.40
25/08/82	KM 12B	.032	.60	.055	124.0	4.80	7.18	8.8	44	1.30	5.130	4.40
25/08/82	KM 12C	.034	.62	.055	125.0	5.90	7.26	8.8	48	.93	4.820	4.40
25/08/82	KM 18A	.033	.61	.035	128.0	4.90	7.06	8.5	48	.83	4.680	6.30
25/08/82	KM 18B	.028	.59	.035	128.0	5.10	7.10	8.5	48	.87	4.510	6.35
25/08/82	KM 18C	.028	.59	.035	128.0	4.60	7.16	8.5	42	.91	4.200	6.30
25/08/82	KM 22A	.029	.60	.055	126.0	4.00	7.31	8.2	50	.76	4.090	5.50
25/08/82	KM 22B	.026	.60	.055	126.0	4.30	7.20	8.1	46	.68	4.210	5.45
25/08/82	KM 22C	.027	.58	.055	126.0	4.10	7.33	8.2	46	.66	3.740	5.50
25/08/82	KM 28A	.027	.57	.075	124.0	3.70	7.16	7.2	46	.62	3.580	4.70
25/08/82	KM 28B	.028	.58	.075	124.0	3.70	7.20	7.3	48	.62	3.920	4.65
25/08/82	KM 28C	.027	.60	.075	125.0	3.50	7.16	7.3	48	.72	3.620	4.75
25/08/82	KM 34A	.126	.60	.045	128.0	4.60	7.15	8.3	46	.65	3.430	5.75
25/08/82	KM 34B	.023	.58	.055	128.0	3.40	7.12	8.5	48	.53	3.660	5.75
25/08/82	KM 34C	.150	.59	.055	128.0	4.00	7.11	8.4	50	.59	3.580	5.75
25/08/82	KM 40A	.162	.59	.030	132.0	3.50	7.30	8.5	50	.54	3.080	6.15
25/08/82	KM 40B	.145	.60	.035	132.0	3.50	7.20	8.5	48	.54	3.020	6.15
25/08/82	KM 40C	.149	.59	.045	136.0	3.70	7.17	8.5	50	.56	2.780	6.15

Table G

Mattagami River
Cross Sections

Kilometer	Date	Distance Across Feet	Distance Across Meters	Average Depth Feet	Average Depth Meters
	June				
1	24	360	109.7	12	3.7
2	24	360	109.7	9.4	2.9
3	24	370	112.8	7.7	2.3
4	24	330	100.6	10.8	3.3
5	24	340	103.6	10.1	3.1
6	24	350	106.7	9.9	3.0
7	24	370	112.8	9.8	3.0
8	24	390	118.9	11.0	3.3
9	24	390	118.9	8.5	2.6
10	24	330	100.6	9.4	2.9
11	24	370	112.8	10.5	3.2
12	24	360	109.7	6.8	2.1
13	24	520	158.5	5.7	1.7
14	24	440	134.1	6.8	2.1
15	24	500	152.4	4.8	1.5
16	24	420	128.0	6.5	2.0
17	24	450	137.2	5.9	1.8
18	24	485	147.8	5.0	1.5
	July				
20	27	505	153.9	3.2	0.96
22	27	465	141.7	3.4	1.04
24	06	405	123.4	5.1	1.6
26	06	380	115.8	4.6	1.4
28	06	440	134.1	3.4	1.0
30	08	635	193.5	4.0	1.2
32	08	475	144.8	8.0	2.4
34	27	465	141.7	6.9	2.12
36	27	385	117.3	3.6	1.10
38	27	660	201.2	6.7	2.02
40	27	560	170.7	9.2	2.8

Table H

Mattagami River

Time of Travel Relationship

Reach	ToT @ 52.95m³/s (days)	A
0.7→6	.41	.731
6→12	.36	.683
12→18	.40	.683
18→22	.12	.999
22→28	.29	.312
28→34	.25	.361
34→40	.29	.424

$ToT_Q = ToT_I(52.95/Q)^{A_I}$

ToT_Q: Time of Travel @ discharge Q

ToT_I: Time of Travel @ 52.95 m³/s for reach I

A_I: ToT exponent for reach I

Ontario

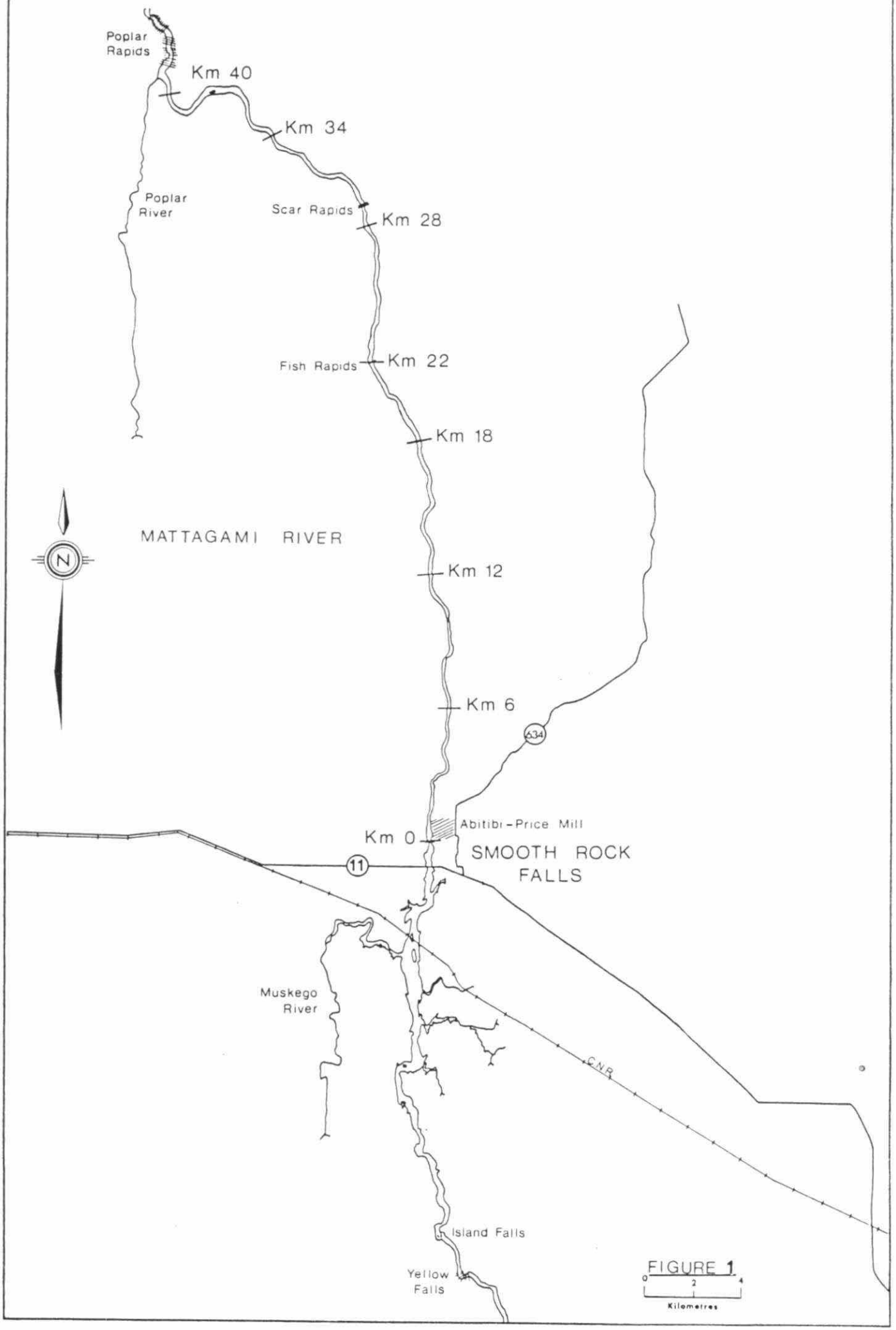

FIGURE 1

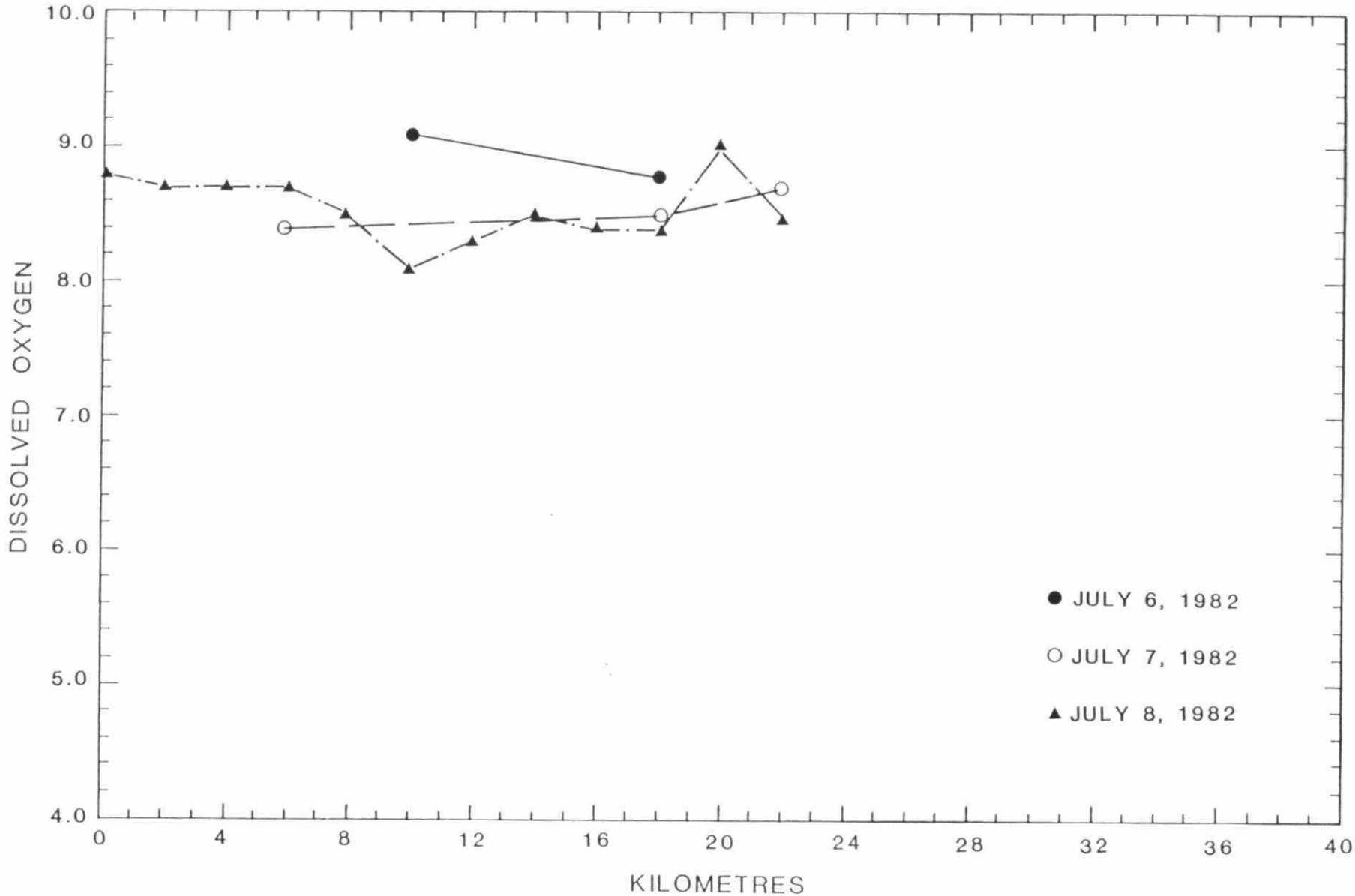

Figure 2A : Mattagami River Dissolved Oxygen Readings
July 6-8, 1982

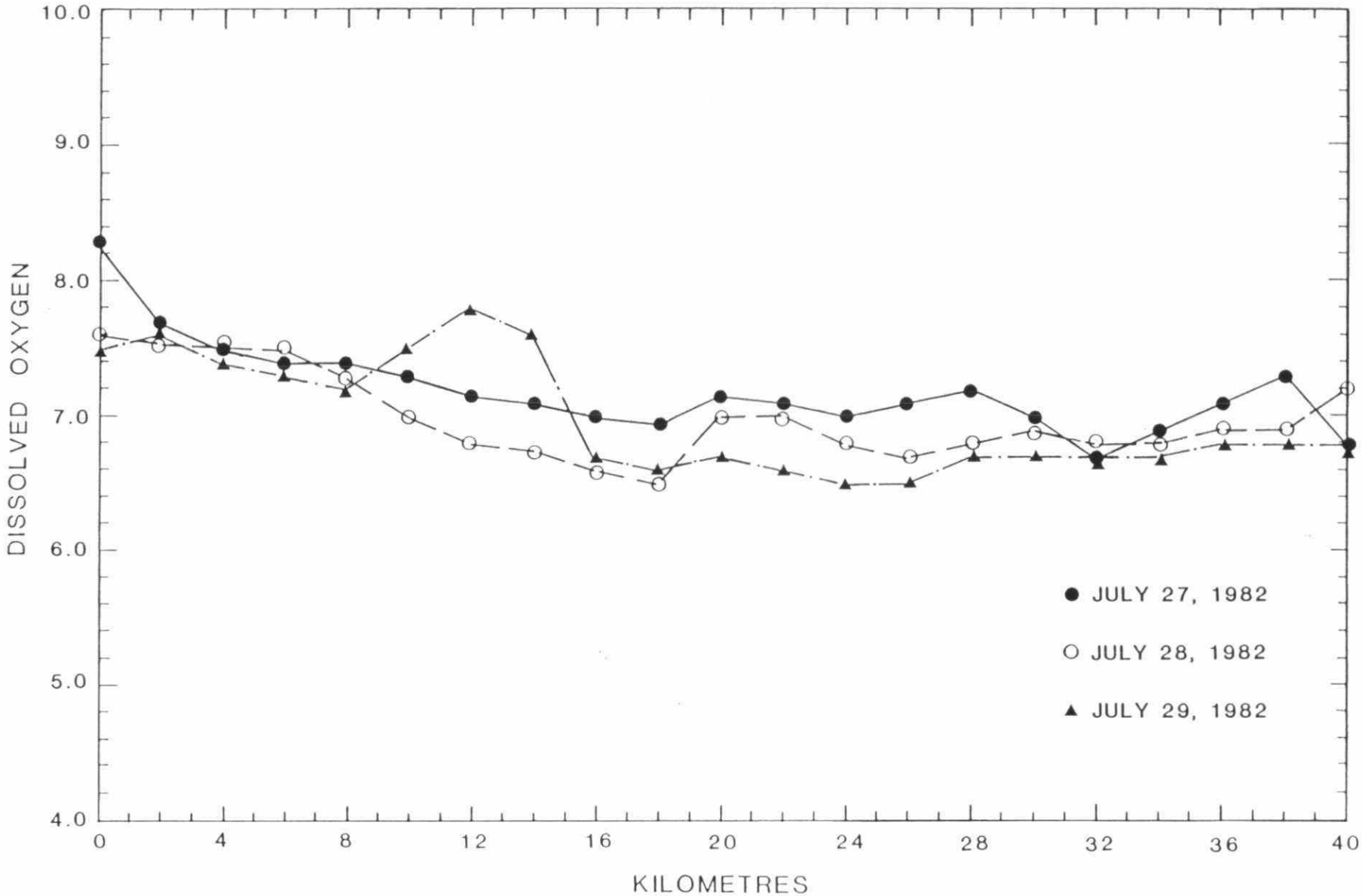

Figure 2B : Mattagami River Dissolved Oxygen Readings
July 27-29, 1982

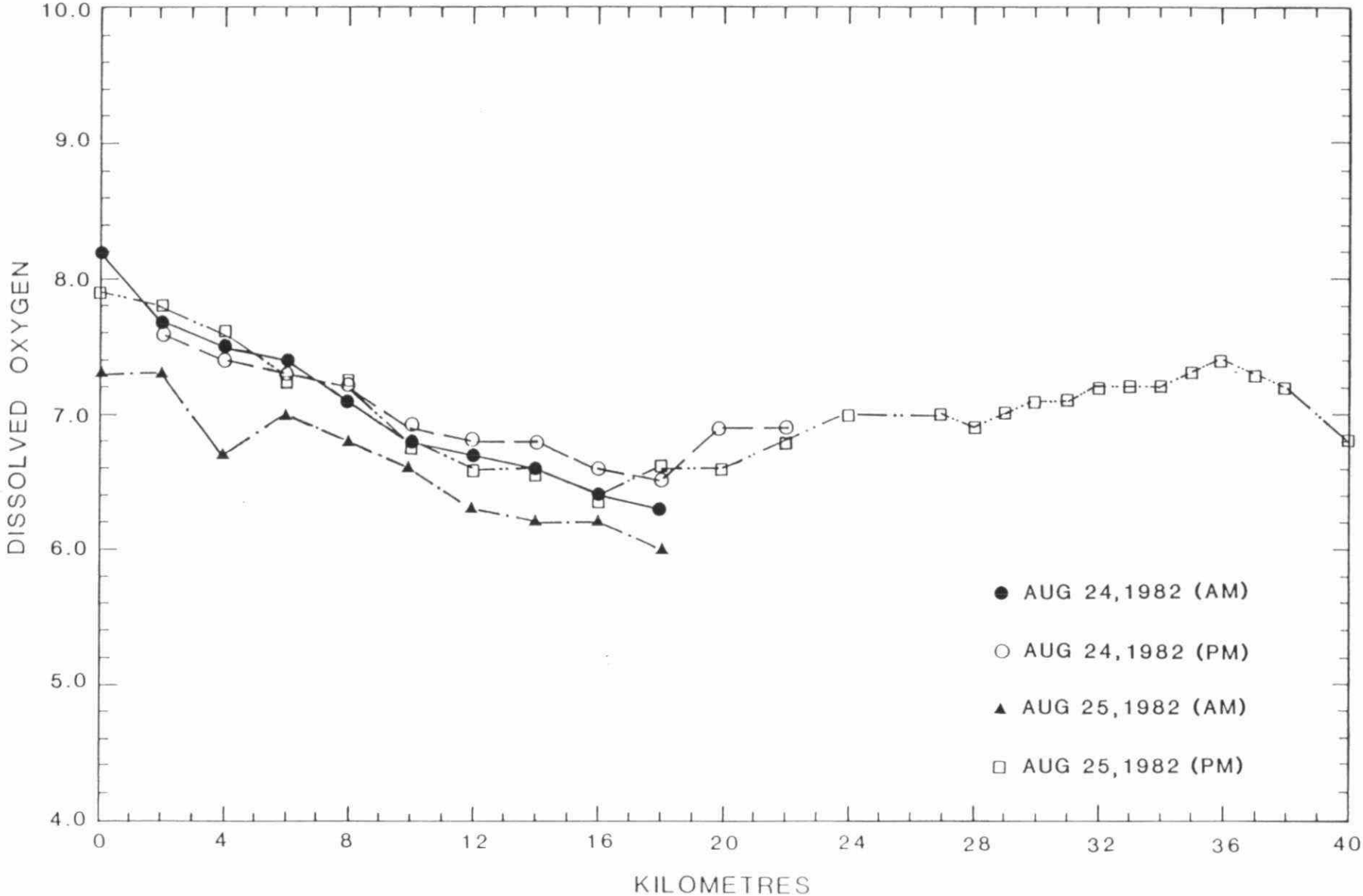

Figure 2C : Mattagami River Dissolved Oxygen Readings
August 24-25, 1982

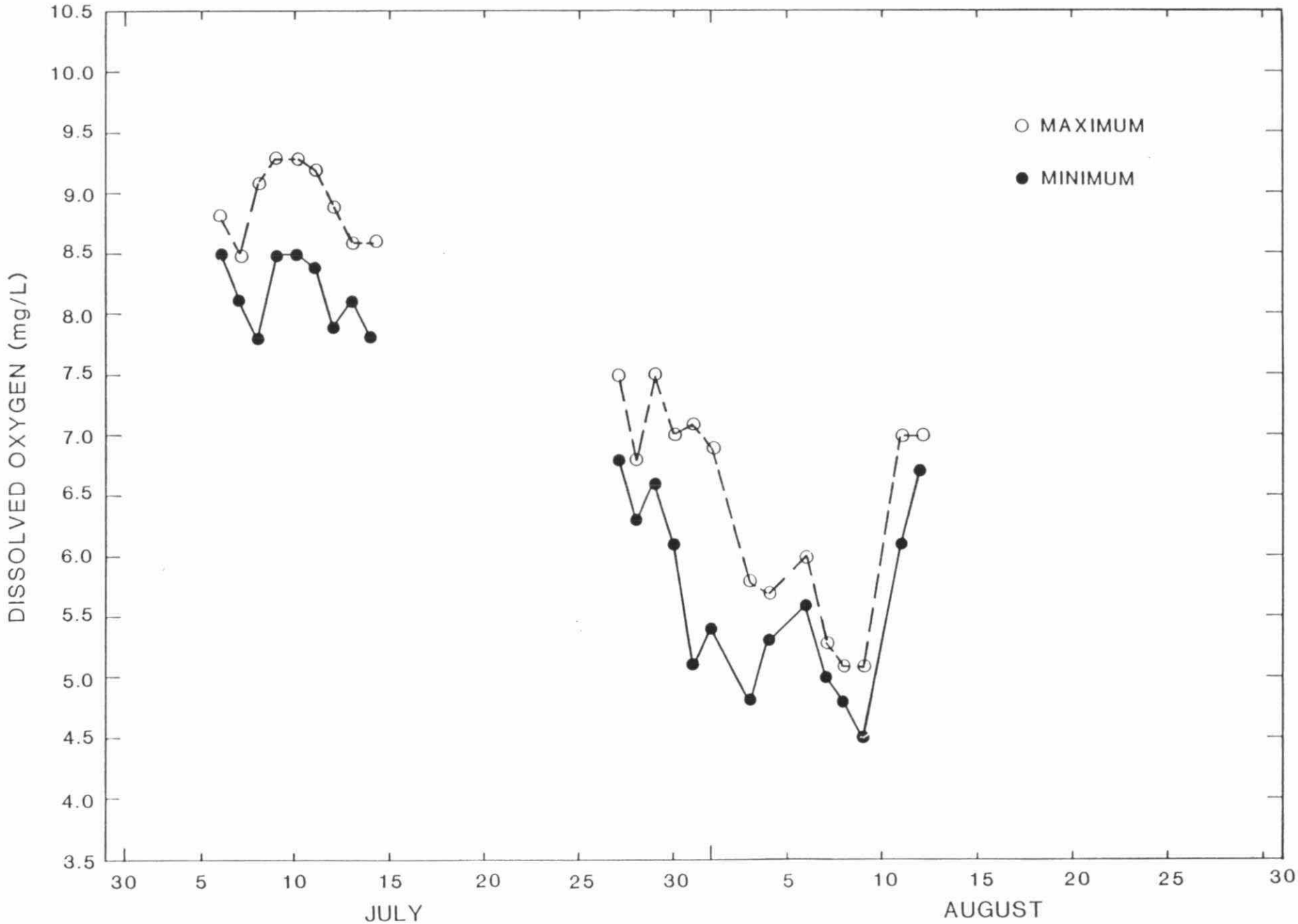

Figure 3 : Mattagami River Dissolved Oxygen KM. 18 – 1982

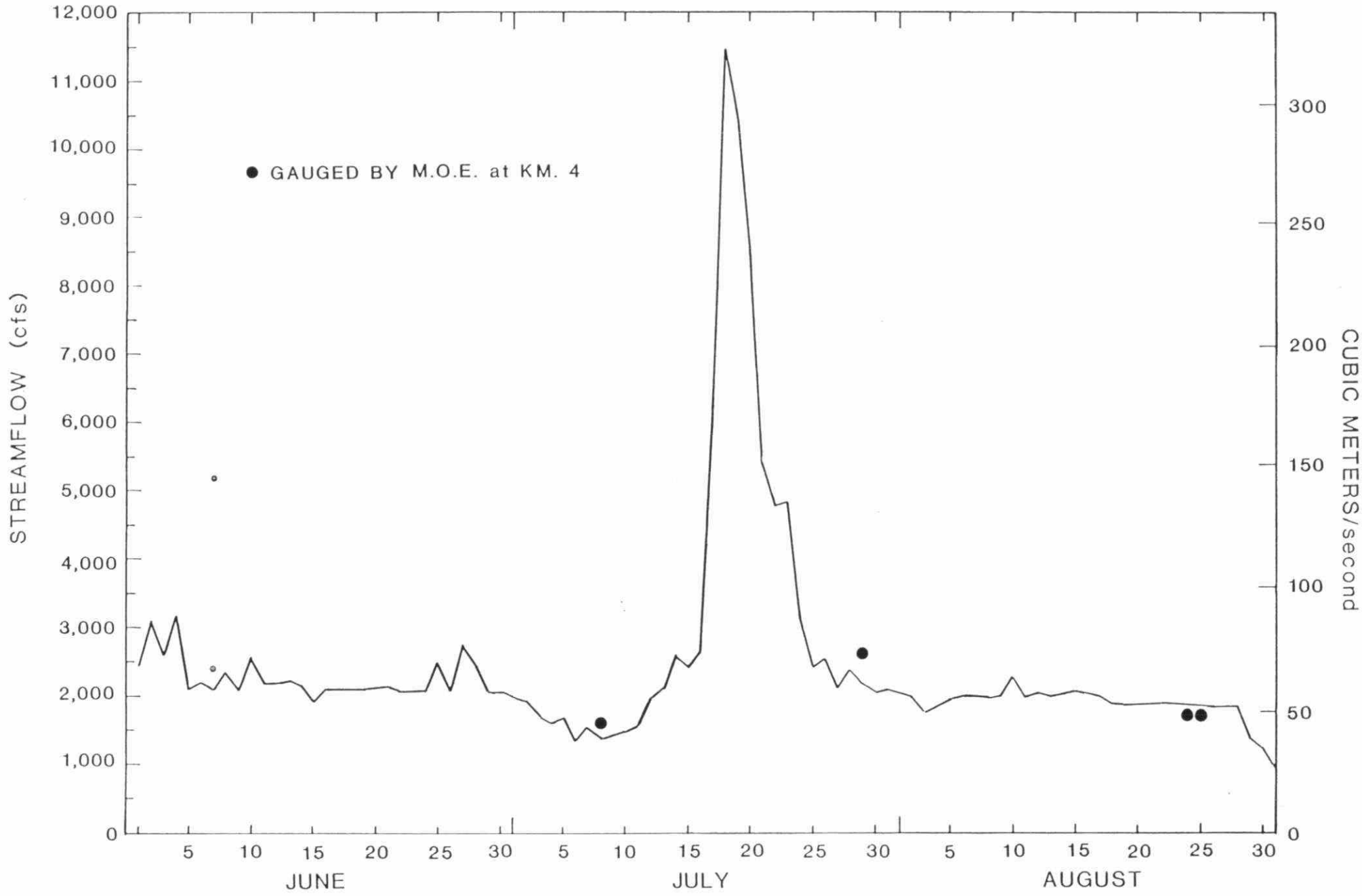

Figure 4 : Mattagami River Streamflow 1982 - Data Provided by Abitibi

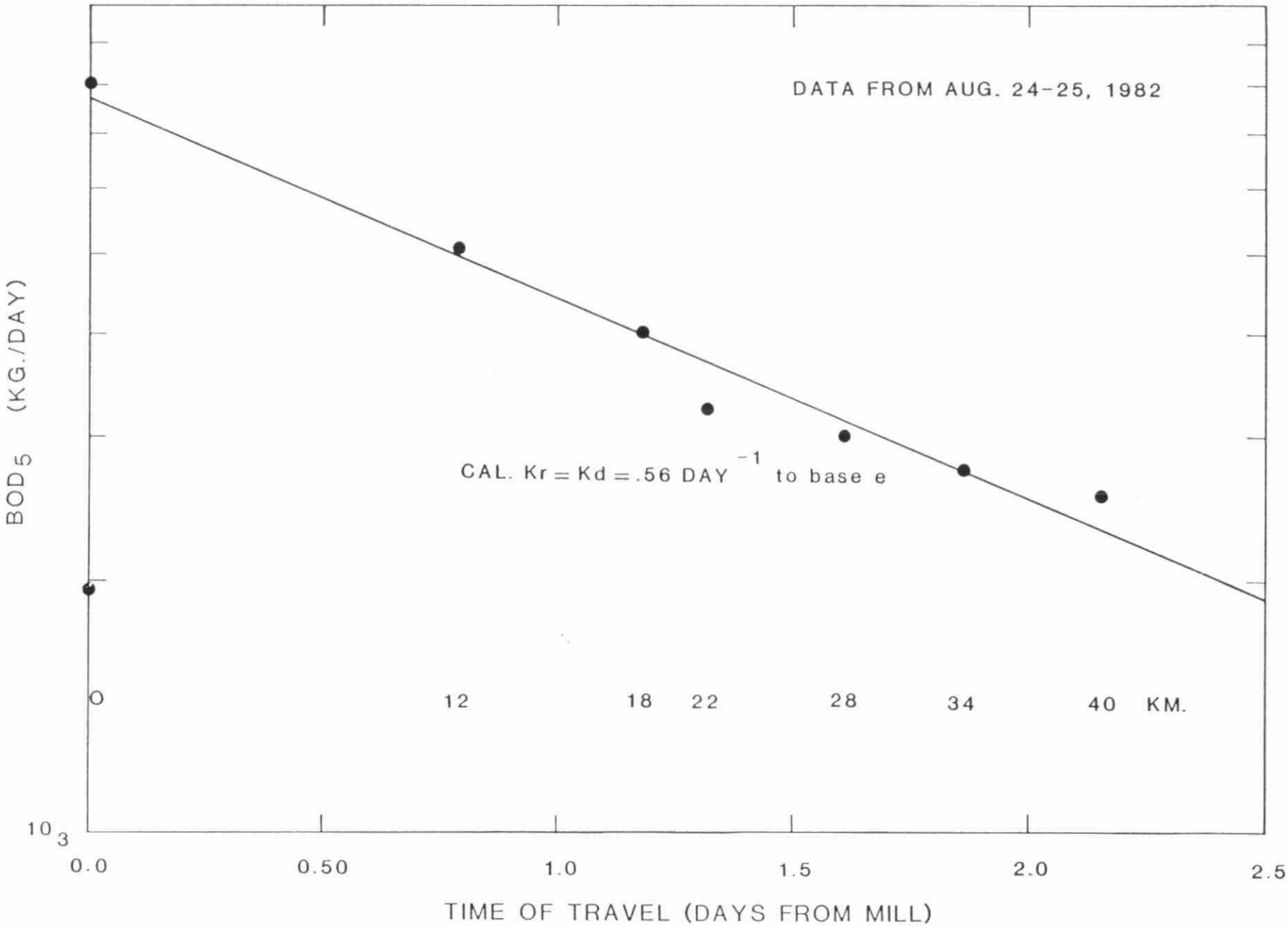

Figure 5 : Mattagami River Kr and Kd

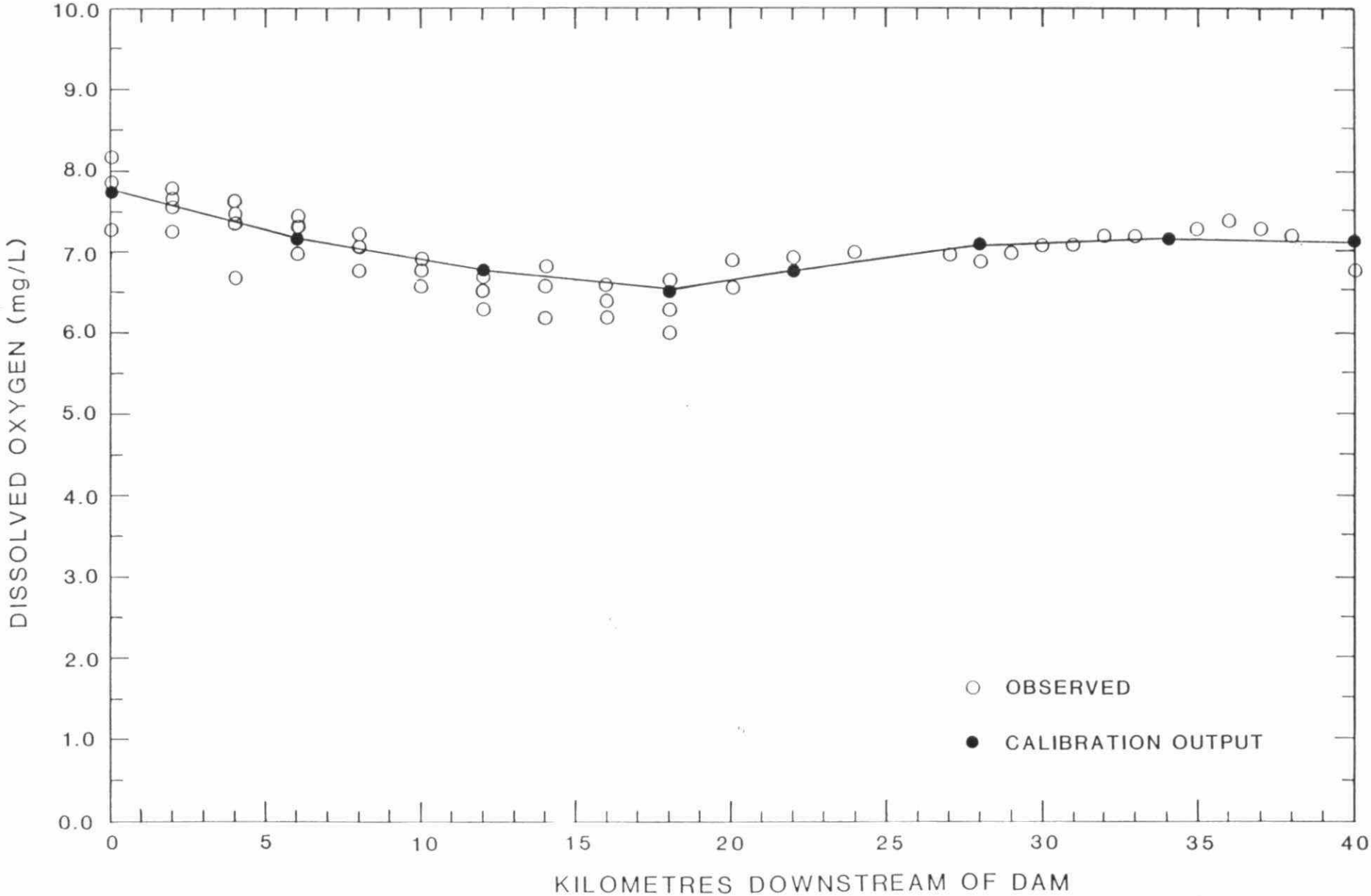

Figure 6 : Mattagami River Calibration August 24/25,1982

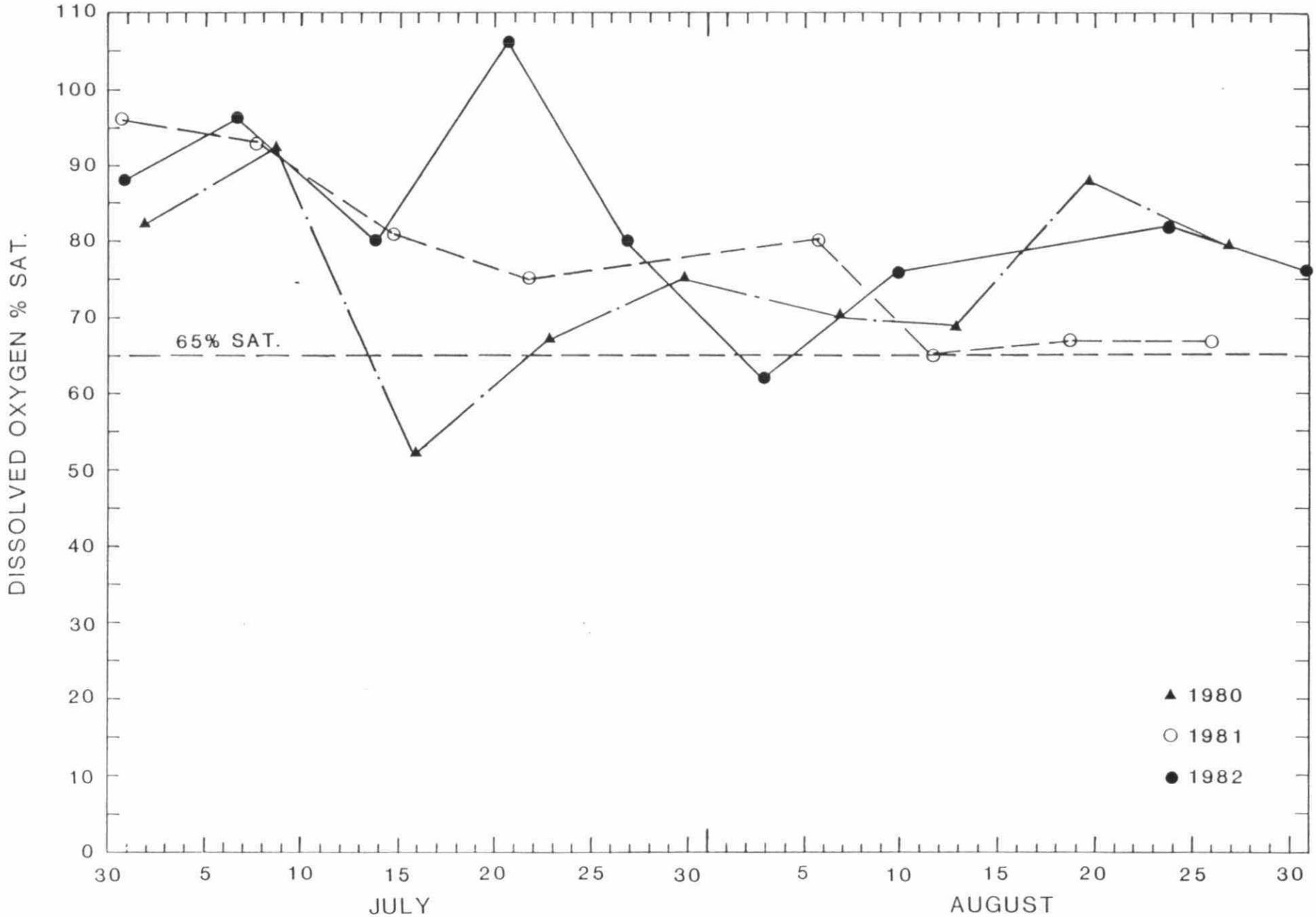

Figure 7 : Mattagami River Dissolved Oxygen at Highway No. 11 : 1980,1981,1982

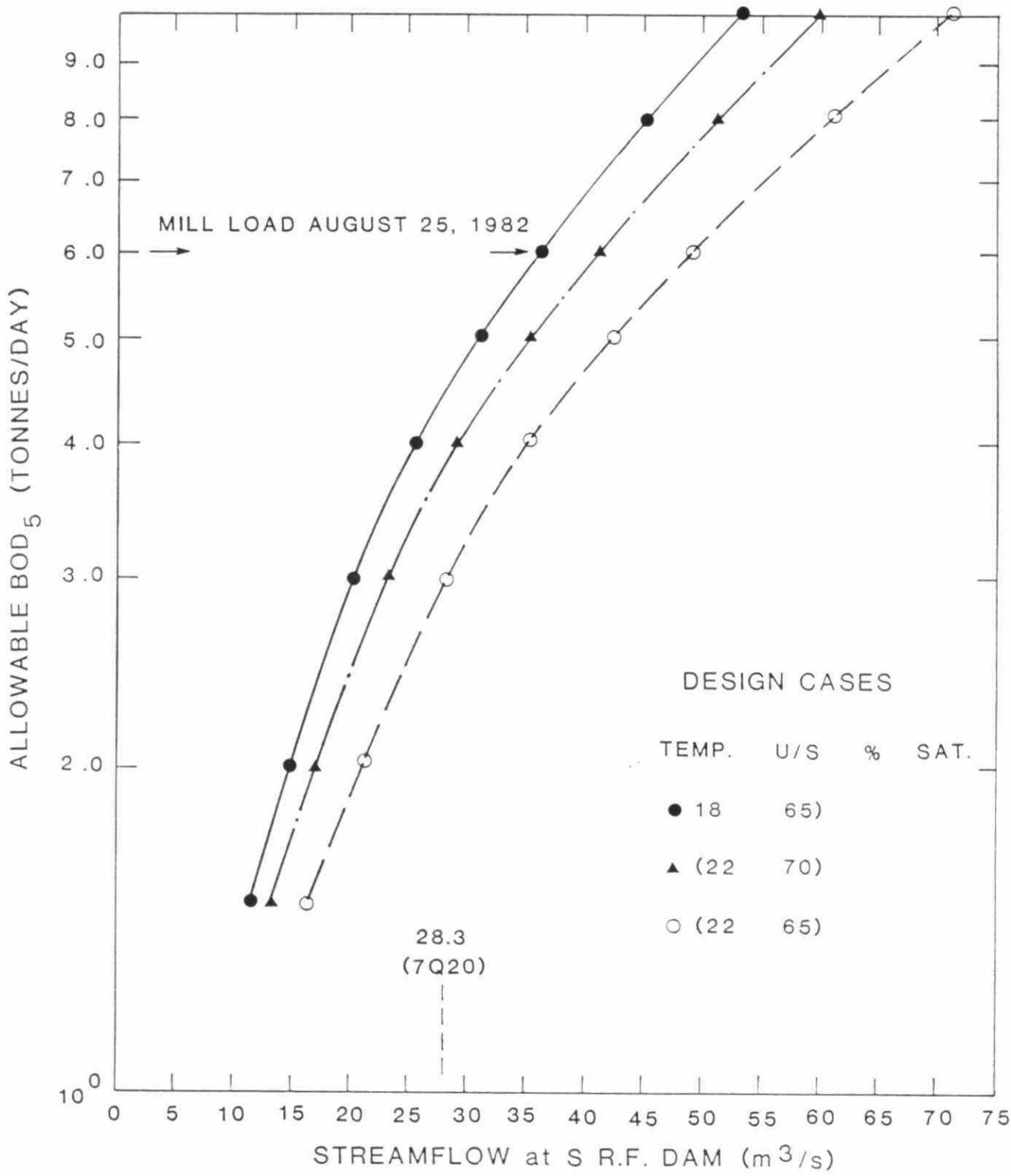

Figure 8 : Mattagami River Allowable Load

APPENDIX

Equipment List

1. Portable Dissolved Oxygen Meter
   - Yellow Springs Instruments Co.
   - Model 54BP
   - calibrated against saturated water

2. Recording Dissolved Oxygen/Temperature Meter
   - Yellow Springs Instruments Co.
   - Model 56
   - calibrated against saturated water

3. Fluorometer
   - Turner Designs
   - Model 10
   - Equipped with flow-through cuvette

4. Fluorescent Dye
   - Rhodamine WT
   - Supplied by Crompton and Knowles of Canada Ltd.

5. Optical Range Finder
   - Coincidence Range finder
   - Wild Heerbrugg Ltd.
   - Model TM10-10A

6. Recording Depth Sounder
   - Lawrance Electronics Inc.
   - Model LRG-1510B

7. Sediment Dredge
   - 6" x 6" Ponar type
   - Supplied by: Guelph Research Instruments

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